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Conservation practices and gully erosion contributions in the Topashaw Canal watershed

G.V. Wilson, F.D. Shields Jr., R.L. Bingner, P. Reid-Rhoades, D.A. DiCarlo, and S.M. Dabney

Abstract: Quantifying the effectiveness of conservation practices at the watershed scale throughout the nation has been identified as a critical need. Our objective was to determine the effectiveness of these conservation practices for reducing sediment yield. The Topashaw Canal watershed (TCW), an 11,000-ha (27,181-ac) area in northcentral Mississippi, exhibits flashy stream response to storms with mean sediment concentrations (117 mg L^{-1} [117 ppm]) almost double the median sediment concentration (60 mg L^{-1}). The most prevalent conservation practice imposed by acreage, since 1985, is enrollment in the Conservation Reserve Program (e.g., planting of pine trees). Grade-stabilization structures (e.g., drop pipes) are the most common conservation practice used to control gully erosion within the TCW. These structures are estimated by the USDA Natural Resources Conservation Service to reduce annual sediment yield from 11.5 to 0.1 Mg ha^{-1} yr^{-1} (5.13 to 0.05 tn ac^{-1} yr^{-1}), but measurements have not been made to determine the accuracy of these estimates. Nonetheless, an average of 58 drop pipes have been installed annually within the TCW using Environmental Quality Incentives Program funds, and an additional 5.4 large drop pipes have been installed each year using US Corps of Engineers funds. Annual gully erosion accounted for 54% of the total sediment yield of over 73,000 Mg (80,445 tn) from TCW. The shift in land use to Conservation Reserve Program, combined with channel incision, has resulted in streambank failure and gully erosion being the primary sources of sediment currently leaving the watershed.

Key words: Conservation Effects Assessment Project (CEAP)—drop pipes—grade-control structures—gully erosion—runoff—streamflow

The 168,750-ha (416,800-ac) Yalobusha River watershed in northcentral Mississippi was selected as a Conservation Effects Assessment Project benchmark watershed in 2003 because of research associated with the Little Topashaw Creek (LTC) stream corridor rehabilitation project. This demonstration erosion control project was a cooperative effort among the US Army Corps of Engineers, USDA Natural Resources Conservation Service (NRCS), and USDA Agricultural Research Service National Sedimentation Laboratory. The LTC stream corridor rehabilitation project objectives included (1) evaluating a cost-effective approach for channel stabilization, (2) evaluating a low-cost approach for stabilizing gully inlets, and (3) quantifying ecological effects of the proposed low-cost measures. Relevant findings including effects of installing large wood structures and planting willow cuttings along eroding channels for stabilization are summarized in table 1.

The Yalobusha River watershed is defined from a point in Grenada Lake upstream from the confluence of the Yalobusha and Skuna Rivers (figure 1). The major environmental concern is soil loss (i.e., sediment). This is typical for streams in the region because gully erosion and streambank failure produce annual sediment yields that are about twice the national average. A primary cause for this soil loss is the channelization initiated during the late 1950s and early 1960s. This process resulted in upstream-migrating knickpoints that have deepened in reaches and tributary channels (Simon and Thomas 2002). Such deepening causes significant channel widening by mass failure of channel banks. Gully inlets are initiated by massive bank failures in upper reaches and gradual migration of headcuts into adjacent fields.

Currently, the number one problem for which conservation funds are allocated in this region is gully erosion (Eddie Carnathan, USDA NRCS, personal communication, 2006). The most common conservation practice (CP) to mitigate the problem is to install grade control structures (i.e., drop pipes; Environmental Quality Incentives Program [EQIP] practice code 410), but the effectiveness of those structures has not been quantified. The Conservation Effects Assessment Project objectives for Topashaw Canal watershed (TCW) were to (1) compile available information on land use, CPs soil characteristics, streamflow, and climate and (2) quantify the effectiveness of drop pipe structures at edge-of-field gully erosion.

Research Approach. The US Geological Survey stream gauge site on Topashaw Canal at Hohenlinden (latitude 33°45'29", longitude 89°10'43") was chosen to define the TCW because it has continuous measurements of both stream discharge and sediment concentration from 2000 to present. The TCW consist of 11,000 ha (27,181 ac), with average annual precipitation of 1,500 mm (59 in) for 2001 to 2006. The highest monthly average (137 mm mo^{-1} [5.4 in $month^{-1}$]) occurred from November through February and lowest period (112 mm mo^{-1} [4.4 in $month^{-1}$]) occurred from July through September. The TCW is instrumented with six rain gauges, a weather station, two edge-of-field gully sites without drop pipes, two edge-of-field gullies with NRCS-constructed drop pipes, an extensive classic gully that is routinely surveyed, and

Glenn V. Wilson is a physical hydrologist at the Watershed Physical Processes Research Unit, **F. Douglas Shields Jr.** is a hydraulic engineer at the Water Quality and Ecology Research Unit, and **Ronald L. Bingner** is an agricultural engineer at the Watershed Physical Processes Research Unit, National Sedimentation Laboratory, USDA Agricultural Research Service, Oxford, Mississippi. **Pamela Reid-Rhoades** is a county operations trainee, USDA Farm Service Agency, Louisville, Mississippi. **David A. DiCarlo** is an assistant professor, Department of Petroleum and Geosystems Engineering, University of Texas, Austin, Texas. **Seth M. Dabney** is an agronomist at the Watershed Physical Processes Research Unit, National Sedimentation Laboratory, USDA Agricultural Research Service.

Table 1
Summary of studies conducted by the Little Topashaw Creek stream corridor rehabilitation project.

Reference	Focus	Findings
Shields (2002, 2003); Shields et al. (2000, 2001, 2004)	Large woody structures description	Large woody structures constructed by stacking harvested trees with the root ball and crown intact 2 m apart in a weave pattern (9 m long and either 2.4 or 3.6 m high) at the toe of steep banks and anchoring the structure into the stream bed and banks. Installed 72 large woody structures along a 1.5 km reach of LTC.
Martin et al. (2002, 2005)	Willows	Planted 3,900 willow cuttings between large woody structures. Preplant soaking increased survival. Soil texture and moisture controlled survival and growth.
Shields et al. (2004)	Large woody performance	A stormflow event three months prior to construction increased the stream width by 10% with bank retreat as great as 7.6 m. Five months after construction, another event damaged many of the large woody structures but they were still conducive to channel stability with about 4.5 m^3 of sediment retained per m of channel, and bank retreat was cut in half. Mean flow velocities of treated reaches were 3% to 72% of the nontreated reaches. Thirty-one percent of large woody structures failed during the first two years, likely due to inadequate anchoring.
Stofleth et al. (2004)	Organic matter retention	Despite the fact that the structures reduced mean flow velocities, there was not an increase in bed carbon concentrations likely due to the fact that nearly 70% of the structures were severely damaged by the end of the third year.
Shields and Knight (2005); Shields et al. (2003); Wu et al. (2005)	Aquatic habitat	Local scour adjacent to large woody structures initially increased baseflow depth and habitat heterogeneity, but as structures degraded these benefits disappeared.
Cooper and Testa (2002); Cooper et al. (2004)	Invertebrate community	Numbers of individuals were very similar after large woody installation while number of taxa increased about 30%. Low diversity before treatment and higher diversity after installation.
Knight et al. (2002)	Fish community	Average fish species richness increased after large woody installation with a shift from small, opportunistic cyprinids to larger centrarchids. Changes in fish population density, size, and community structure mirrored trends in other incised stream ecosystems. Collections were dominated by cyprinids and centrarchids, but the relative dominance of cyprinids was inversely related to the mean water depth.

a stream gauging station for monitoring of streamflow and sediment concentration on the LTC. The weather station monitors wind speed and direction, temperature, relative humidity, barometric pressure, solar radiation, and precipitation at heights above the surface of 300, 200, 200, 150, 300, and 200 cm (118.1, 78.7, 78.7, 59.1, 118.1, and 78.7 in), respectively. The weather station data logger is interfaced with TDR soil probes at depths of 5, 10, 20, 50, and 100 cm (2.0, 3.9, 7.9, 19.7, 39.4 in) for monitoring soil water content, temperature, and salinity.

The LTC within the TCW was chosen for experimental measurement of the effectiveness of drop-pipe structures and gully erosion. This is a fourth-order stream that drains an area of approximately 3,700 ha (9,143 ac). Treated and nontreated gullies within the LTC subwatershed were instrumented to determine the effectiveness of drop-pipe structures. Runoff into two untreated edge-of-field gully inlets without drop-pipe structures was monitored using H-flumes with bubblers for discharge measurement and activation of runoff water samplers. The flume design allowed runoff monitoring and sampling without preventing headcut migration in the gully. Two drop pipes, adjacent to the two untreated gully inlets, were monitored by installing smooth-walled pipes inside the corrugated drop pipes and instrumented with a velocity meter and pressure transducer set approximately 2 m (6 ft) back from the mouth for runoff recording and activation of sequential or composite runoff water samplers. An extensive classic gully with two branches exists on the east side of LTC immediately upstream from the stream monitoring site (figure 2). Runoff from the surrounding hillslope is diverted by a berm (EQIP practice code 362) into a ditch that was designed to cut across the field and into a drop pipe at the entrance to LTC. When the drop pipe washed out, a gully rapidly eroded up the ditch and branched into the field because of runoff from crop furrows. The large gully and instrumented fields are routinely surveyed for soil loss measurement.

Watershed Description. The TCW (figure 3) is characterized by relatively flat (<2%)

Figure 1
Location and boundary of Mississippi's original Yalobusha River watershed, along with locations of US Geological Survey (USGS) and USDA Agricultural Research Service (ARS) National Sedimentation Laboratory (NSL) stream gauge stations.

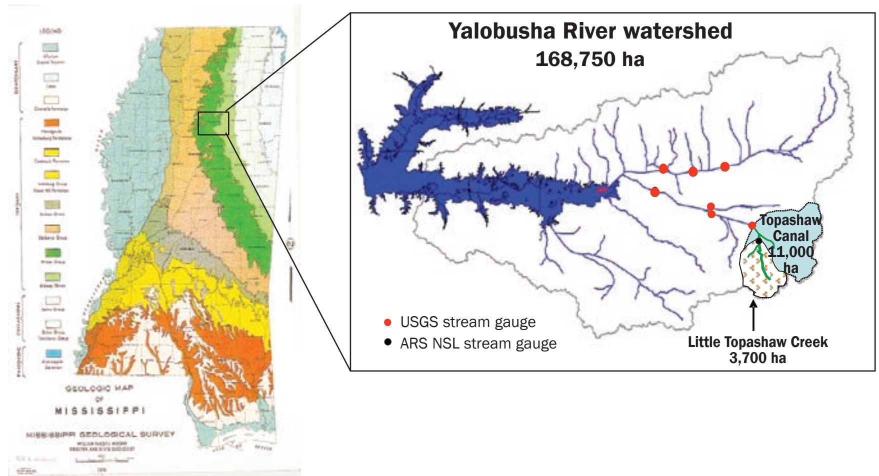


Figure 2
(a) Large gully along the ditch, and (b) the branch into the field.

(a) **(b)**

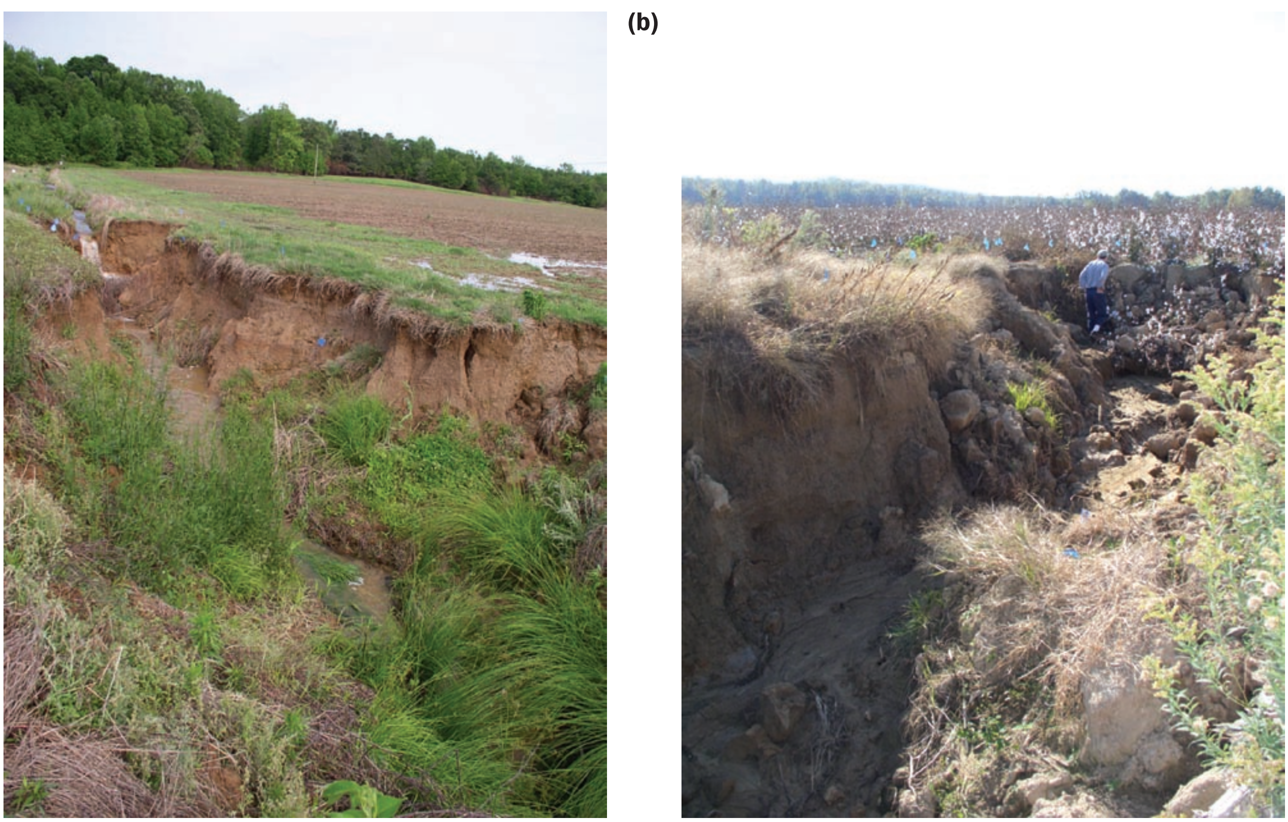
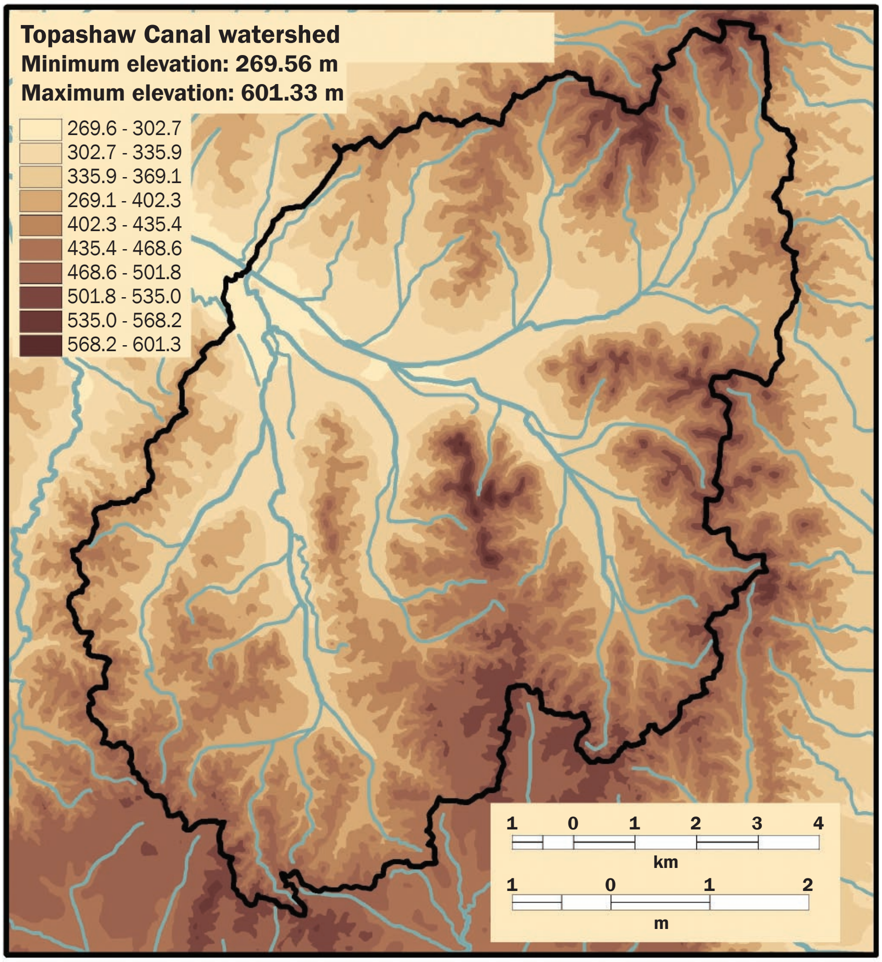


Figure 3
Digital elevation model of the Topashaw Canal watershed.



alluvial plains along streams and fairly steep (>12%) forested hillslopes. Land use consists of 11% cropland, 6% pasture or grassed areas, 80% forested areas, 2% urban, and 1% wetland and surface water (figure 4). The primary crops grown are sweet potatoes (*Ipomoea batatus*) in rotation with either corn (*Zea mays*), cotton (*Gossypium hirsutum*), or to a lesser extent soybean (*Glycine max*). Corn and cotton are often grown in three year cycles with no-till management, followed by re-establishment of rows for sweet potato production. The watershed lies within the Southern Coastal Plain, major land resource area 133A and has 25 predominant soil series (figure 5 and table 2). Row-crop agriculture is limited to the alluvial plains, which are predominantly Falaya silt loam and occupy approximately 11% of the watershed area. The forested hillslopes are predominantly Sweatman loam occupying 46% of the watershed area. The dominant geologic formation is the Midway Group, characterized by dispersive silt soils at the surface (upper meter), overlying layers with high sand content and lenses of increased clay content indicative of the alluvial deposition patterns. These layers overlie consolidated clay materials that generally serve as the stream bed. It is the resistant, consolidated clay bed material that makes the TCW somewhat unique in comparison to other adjusting stream systems in the mid-continent region.

Regional geology is characterized by dispersive silt and clay soils overlying sand that overlies consolidated cohesive material. Subsurface flow is common, and water perched by clay layers erodes the highly conductive sandy layers above. Undercutting, as a result of the seepage erosion, leaves the streambank susceptible to bank failure (Wilson et al. 2007). Although the channel beds are comprised primarily of sand with median sizes between 0.2 and 0.3 mm (0.008 and 0.012 in), cohesive materials occur as massive outcrops and as gravel-sized particles. The channel is tortuous, with an average sinuosity of 2.1, an average width of 35 m (115 ft), and an average depth of 6 m (20 ft). Available evidence suggests mean width has increased by a factor of four to five since 1955. Concave banks on the outside of meander bends are failing by mass wasting and sand is accreting on large point bars opposite failing banks. Outside of bends, eroding banks frequently invade adjacent cultivated fields while inside bends and abandoned sloughs are vegetated with a diverse mixture of hardwood trees and associated species.

Current Conservation Practices. A census of CPs installed within the TCW by various governmental agencies (USDA NRCS, USDA Farm Service Agency, and US Army Corps of Engineers) was compiled (Reid-Rhoades et al. 2008) by collecting land management history for tracts that are currently or have participated in conservation incentive programs. The programs included EQIP, the Conservation Reserve Program (CRP), and special regional erosion control projects. Descriptive data were entered into spreadsheets with the funded conservation program identified by tract number and sensitive information (e.g., landowner identifiers) removed. Spatial coordinates associated with each CP were recorded to prepare data sets for watershed modeling with Agricultural Non-Point Source (AGNPS) model (Bingner and Theurer 2001) and the Soil and Water Assessment Tool (SWAT) (Arnold et al. 1998). This was done using 1996 aerial photographs from the Farm Service Agency offices with the tract numbers for each funded CP identified. Satellite imagery for December of 2006 provided current aerial photography of land use. These images were verified by making Global positioning system measurements at about 30 known points within the TCW that were easily identified in the images. The CP data were interpolated into spatial information through the creation of digitized polygons using scanned aerial photos that associate land use management schemes with tract numbers. Land use practices that were not included in government incentive programs were compiled from agency data and satellite imagery.

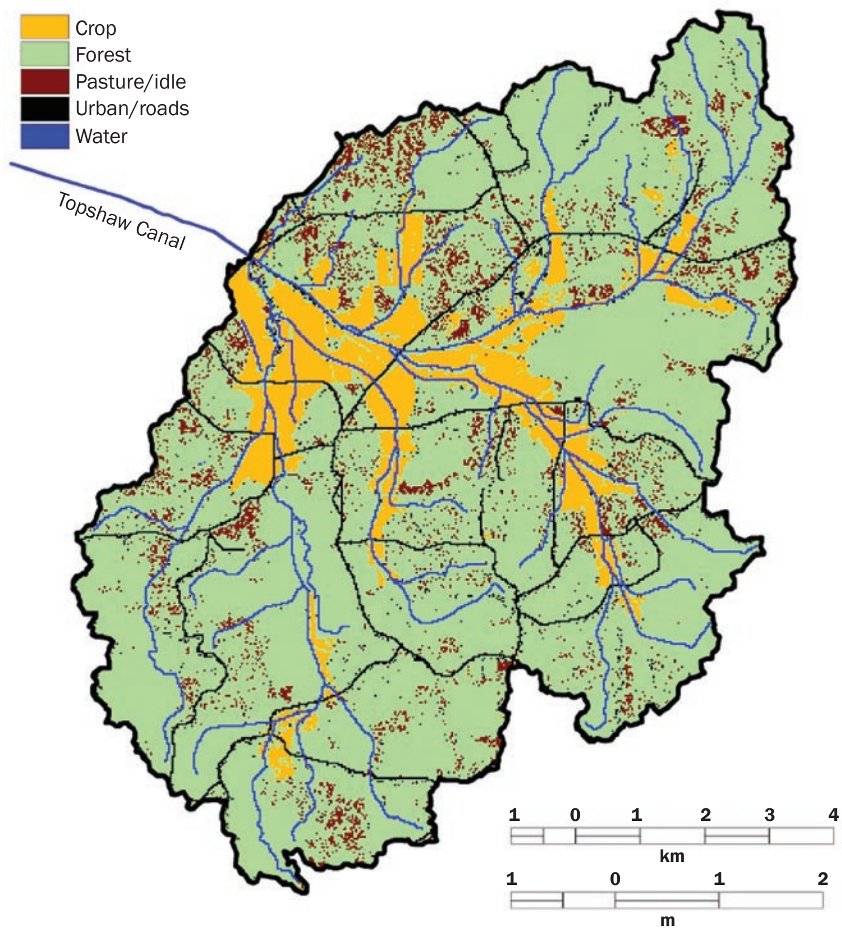
Results and Discussion

Conservation Practices. Conservation practices that impact current and future hydrology and water quality behavior have been applied in the TCW for decades. The most significant were the channelization activities and the Yazoo-Little Tallahatchie project (predominantly tree planting) programs that began in the 1950s. For the Conservation Effects Assessment Project, we focused on the conservation programs implemented during the last two decades under the US farm bill (Reid-Rhoades et al. 2008). The initial conservation program in the TCW was CRP with funded acreage varying significantly during the early years (figure 6). Conservation Reserve Program acreage reached a peak of over 4,585 ha (11,330 ac) and cost approximately \$489,000 in 1987, but for five years in the 1990s, no acreage was enrolled. Interest in and sign-up for CRP began again in 1997 but dwindled to less than 2000 ha (4,942 ac) with payments of \$20,000 per year once EQIP was initiated in 2002. Environmental Quality Incentives Program sign-ups reached a peak acreage (5,000 ha [12,355 ac]) and funds of \$583,000 in 2003. The total acreage and funds since 1985 in the TCW are 13,300 ha (32,864 ac) and \$1,276,000 for CRP and 11,000 ha (27,180 ac) and \$944,000 for EQIP.

The most common CPs, in both funds and acreage, applied in the TCW are listed in table 3. The acreage associated with grade stabilization represents an estimate of the drainage area contributing to the drop pipe. Grade stabilization through EQIP is the practice that the most funds are used for. The CRP practice of planting of pines accounts for almost one third of all practices in CRP and EQIP programs combined. When combined with other practices involving forest establishment and management, forestry accounts for nearly 39% of the acreage and 30% of the CP funds applied in the watershed not counting grade stabilization structures. Grass is the next largest CP and when combined with other similar CPs dealing with pasture land, this category constitutes about 30% of the acreage and funds. The acreage left in row-crop production is almost exclusively the flat alluvial plains adjacent to the streams.

Figure 4

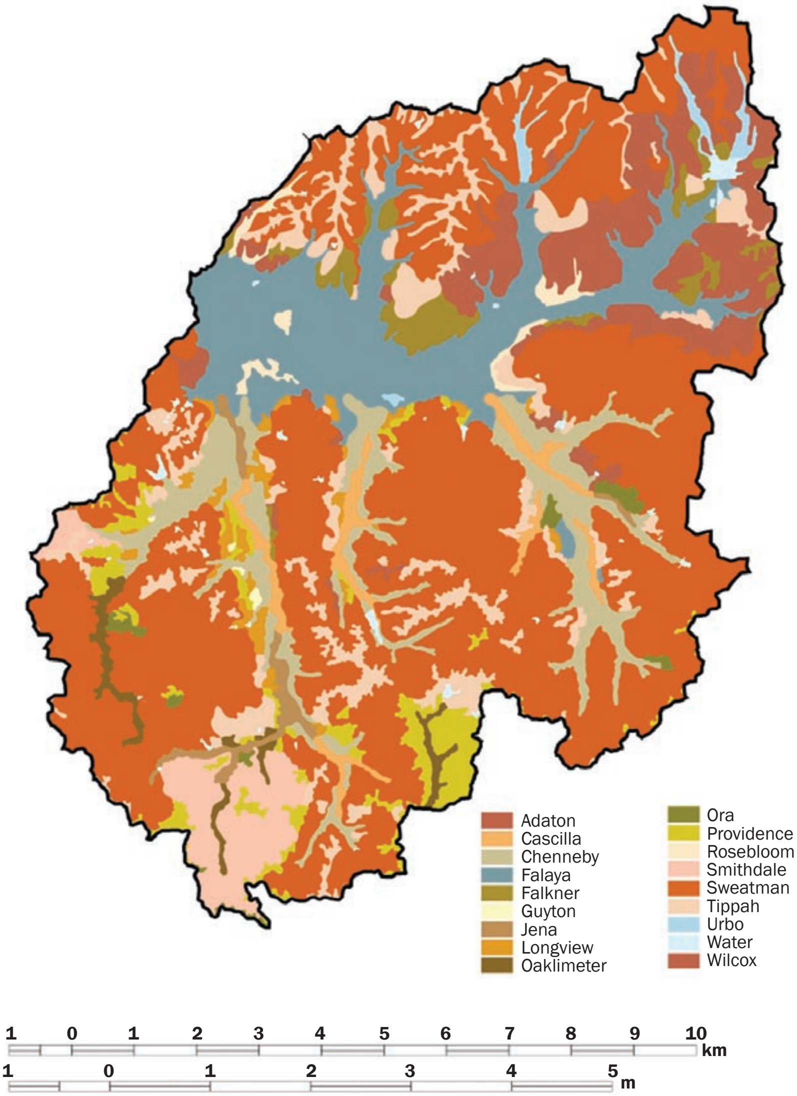
Land use map for the Topashaw Canal watershed.



Stream Response. Discrete, time-sequenced streamflow and sediment samples from multiple storm events at the LTC site in 2006 were used to develop a second degree polynomial sediment rating curve. This curve was verified by comparing estimated LTC sediment concentrations with US Geological Survey concentrations for the TCW at the downstream Hohenlinden site (figure 7). Sediment concentrations were highly skewed due to the flashy hydrologic response to storm events. The break-point data mean and median sediment concentrations for LTC were 118 and 41 mg L^{-1} (118 and 41 ppm), respectively, for the 2000 to 2006 period of record. Daily mean and median sediment concentrations for TCW were 117 and 60 mg L^{-1}. Based on the LTC rating and measurements by US Geological Survey at the Hohenlinden (TCW), annual sediment loads of approximately 19,862 Mg (21,888 tn) were lost from LTC and 73,313 Mg (80,790 tn) from TCW. It appears that the sediment transport capacity of the stream at LTC gauging station was not exceeded as sediment concentrations and annual soil losses increased proportionally with the increased scale from 5.4 Mg ha^{-1} y^{-1} (2.4 tn ac^{-1} yr^{-1}) for LTC to 6.7 Mg ha^{-1} y^{-1} (3.0 tn ac^{-1} yr^{-1}) for TCW. A scale effect was also evident in the variability which tended to decrease with increased size of the watershed. The coefficient of variation in annual sediment yield for LTC was 79% as compared to just 10% for TCW. This was also evident in annual discharge which averaged 4,800 m^3 ha^{-1} y^{-1} (513,120 gal ac^{-1} yr^{-1}) with a coefficient of variation of 31% for LTC as compared to 6,300 m^3 ha^{-1} y^{-1} (673,470 gal ac^{-1} yr^{-1}) and a coefficient of variation of only 20% for TCW.

Gully Erosion. The application for EQIP funds for a grade stabilization structure, i.e. a drop-pipe, includes an estimate of the soil lost by gully erosion based upon dimensions of the void. The formula does not calculate the whole volume "voided" by the gully but only the current year "active" gully erosion. A total of 213 drop-pipes (~58 per year) were installed in the TCW through EQIP since

Figure 5
The soil series distribution within the Topashaw Canal watershed.



2002. The annual total has increased slightly (figure 8) and therefore the estimate of annual soil loss by gully erosion has increased. The mean annual soil loss by gully erosion estimated from the EQIP data was 10,200 Mg ha^{-1} (11,240 tn ac^{-1}). This suggests that annual soil loss by gully erosion is around 14% of the total sediment yield 73,313 Mg y^{-1} (80,800 tn yr^{-1}) for the TCW. However, this gully erosion value is conservative because it does not represent the total soil loss by gullies in the watershed, only those gullies remediated under EQIP. Additionally, EQIP funds are only used to remediate small gullies, whereas, the large classic gullies, such as the one being surveyed in LTC, are remediated by the US Army Corps of Engineers.

The conservative nature of the gully erosion estimate is highlighted by the time series of gully volumes measured at the large classical gully study site (figure 9). Since 2005, when the gully formed because of failure of a drop pipe, the gully progressed rapidly up a diversion ditch and branched into an agricultural field (figure 2). The total soil loss from this single gully was approximately 8,360 Mg (9,217 tn), which is nearly as much as the total soil lost from all the small gullies in the watershed remediated through the EQIP program. The time that the drop pipe failed is unknown, so an initial gully erosion rate cannot be estimated. Assuming that the gully was a year old at the time of the first survey, March 25, 2005, the annual soil loss was 5,390 Mg y^{-1} (5,942 tn yr^{-1}) from this single gully which is still around 50% of the annual soil loss by gullies recorded through EQIP and 7% of the total annual soil loss from the TCW.

Gully erosion since March 25, 2005, indicates soil losses at rates of 1690, 1674, and 719 Mg y^{-1} (1863, 1846, and 793 tn yr^{-1}) respectively, based on surveys on May 3, 2006, December 5, 2006, and January 30, 2007. These extreme erosion rates resulted in a gully that averaged 1.5 m (4.9 ft) in depth at the head with a maximum depth of 5.0 m (16.4 ft) near the mouth. The headcut progressed at the four survey dates to linear distances of 84, 98, 114, and 128 m (276, 322, 374, and 420 ft) along the main branch up the ditch, and linear distances of 31, 55, 65 and 67 m (102, 180, 213, and 220 ft) along the branch into the agricultural field. While these rates of erosion seem extraordinary, there are reportedly more extensive gullies elsewhere in the watershed (personal communication with landowners, 2007).

Applications for grade stabilization funds to remedy the large-scale gullies through the US Army Corps of Engineers do not include estimates of the volume of the gully or mass of soil loss. However, if one were to assume that the initial soil loss of 5,390 Mg y^{-1} (5,942 tn yr^{-1}) is typical of these large gullies, it would take only 12 of these large gullies, in combination with the 58 small gullies annually remediated through EQIP, to equal the sediment yield from the TCW. Data from 1997 to 2004 indicate that the US Army Corps of Engineers remediates an average of 5.4 large gullies annually in the TCW.

It is recognized that not all of the soil entering streams from these gullies will reach the mouth of the watershed. Given that these gullies are typically eroding the upper 2 m (7 ft), soil loss is predominantly silt-size material and is therefore less susceptible to deposition. Also, since this sediment will experience deposition and resuspension, there can be a time lag of many years in sediment production and yield from the source to the Hohenlinden gauge. These results indicate that gully erosion is a significant contributor in that the combination of estimated average annual soil loss from small gullies remediated by EQIP and large gullies remediated by the

Table 2
Soil descriptions for the major soil series in the Topashaw Canal watershed (see figure 4), along with texture, slope, and area.

Series (ID)	Taxonomy	Texture	Slope	Area (ha)
Adaton (Ad)	Fine-silty, mixed active, thermic Typic Endoaqualf	Silt loam	0% to 2%	38.9
Cascilla (Cc)	Fine-silty, mixed, active, thermic Fluventic Dystrudepts	Silt loam	0% to 2%	207.1
Chenneby (Ch)	Fine-silty, mixed, active, thermic Fluvaquentic Dystrudept	Silt loam	0% to 2%	745.5
Falaya (Fa)	Coarse silty, mixed, active, acid, thermic Aeric Fluvaquent	Silit loam	0% to 2%	1,268.4
Falkner (Fk)	Fine-silty, siliceous, active, thermic Aquic Paleudalfs	Silit loam	0% to 8%	257.2
Guyton (Gy)	Fine-silty, siliceous, active, thermic Typic Glossaqualfs	Silt loam	0% to 1%	7.9
Jena (Je)	Coarse-loamy, siliceous, active, thermic Fluventic Dystrudept	Fine sand loam	0% to 2%	106.8
Longview (Lo)	Fine-silty, siliceous, active, thermic, Glossaquic Happludalf	Silt loam	0% to 2%	135.6
Oaklimeter (Oa)	Coarse-silty, mixed, active, thermic Fluvaquentic Dystrudept	Silt loam	0% to 2%	111.8
Ora (Or)	Fine-loamy, siliceous, semiactive, thermic Typic Fragiudult	Loam	5% to 12%	74.8
Providence (Pr)	Fine-silty, mixed, active, thermic Oxyaquic Fragiudalf	Silt loam	2% to 12%	436.9
Rosebloom (Ro)	Fine-silty, mixed, active, acid, thermic, Fluvaquentic Endoaquept	Silt loam	0% to 2%	89.3
Smithdale (Sm)	Fine-loamy, siliceous, subactive, thermic Typic Hapludult	Loam	12 % to 45%	397.2
Sweatman (Sw)	Fine, mixed, semiactive, thermic Typic Hapludult	Loam	12% to 35%	5,145.1
Tippah (Ti)	Fine-silty, mixed, active, thermic, Aquic Paleudalf	Silt loam	2% to 12%	980.8
Urbo (Ur)	Fine, mixed, active, acid, thermic, Vertic Epiaquept	Silt clay loam	0% to 2%	73.3
Wilcox (Wi)	Very-fine, smectitic, thermic Chromic Dystrudert	Silt clay loam	2% to 12%	958.6

US Army Corps of Engineers was equivalent to 54% of the total average annual sediment yield. This is higher than the average gully erosion contribution of 38% reported by USDA NRCS (1997) for the United States but is within the range of 17% to 73% for the 19 states surveyed. This is also higher than reported by Poesen et al. (2003) for the worldwide contribution of gully erosion to total sediment yield, which averaged 44%. Clearly the TCW has a high tendency for gully erosion and a significant need for CPs that control this component of the watershed soil losses.

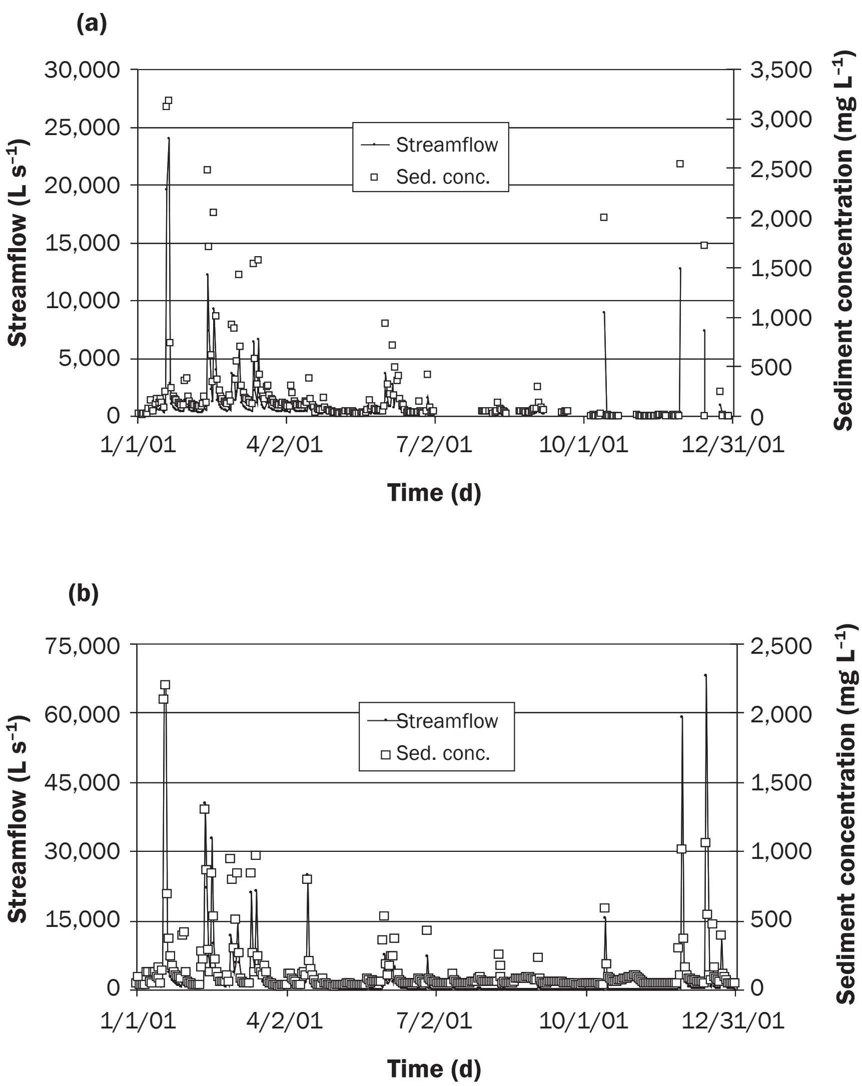
Sediment from streambanks has been reported to account for as much as 30% to 85% of sediment yields in agricultural watersheds such as TCW (Grissinger et al. 1991; Simon and Darby 1999; Evans et al. 2006). The estimated contribution of gully erosion to total watershed sediment yield does

Table 3
Summary of conservation practices funded in the Little Topashaw Creek watershed since 1985.

Program	Conservation practice	Conservation practice code	Coverage (ha)	Annual payment $	Annual payment $ ha^{-1}
CRP	Pines	CP3	6,914	626,625	90.63
EQIP	Grade stable	410	5,157	862,189	167.18
CRP	Grass	CP1	2,816	295,636	105.00
EQIP	Grazing	378, 512, 528a, 600, 614, 633, 638, 720, 728, 734, 769	2,783	349,693	125.68
EQIP	Sedimentation	342, 350, 362, 391A, 410	2,574	487,626	189.43
CRP	FRB	CP4	1,768	164,736	93.16
CRP	Established grass	CP10	1,350	139,052	103.00
EQIP	Forestry	381, 612	385	75,718	196.47
EQIP	Forest non-plant	381, 490, 595, 655, 702	228	30,811	134.92
CRP	Grass strip	CP21	164	19,297	117.97
CRP	Established trees	CP11	125	10,557	84.72
CRP	BSW	CP4	96	10,387	108.75
CRP	Hardwood	CP3A	48	8,496	177.91
CRP	WWA	CP9	4	1,577	437.83

Notes: CRP = Conservation Reserve Program; EQIP = Environmental Quality Incentives Program; Pines = planting of pine trees; Grass = planting of grasses; Grazing = conversion to pasture; Sedimentation = installation of berms, basins, ditches (not drop pipes); FRB = mixed species forest riparian buffers; Established Grass = pastures already established in grass; Forestry = planted forest (predominately pines); Forest non-plant = preplant site preparations, harvest, and pest management; Grass strip = grass buffer strips; Established trees = trees already in existence; BSW = mixed species buffer strip for wildlife; Hardwood = planting of hardwoods; and WWA = wildlife wetland area.

Figure 6
Daily streamflow and sediment concentrations for calendar year 2001 at (a) Little Topashaw Creek and (b) at Topashaw Canal watershed (US Geological Survey gauge at Hohenlinden).



not include the contribution of near stream sources such as streambank failure. The influence of reduction in soil shear strength on streambank failure as a result of subsurface flow increasing the soil-water pressure has been emphasized in past streambank failure research (Simon and Curini 1998; Casagli et al. 1999; Simon et al. 2000; Rinaldi et al. 2004). Recent studies on streambank failure at LTC have quantified seepage erosion rates as a result of subsurface flow (Wilson et al. 2007; Fox et al. 2006; Fox et al. 2007a). Wilson et al. (2007) measured seepage erosion from eight seeps along an 800 m (2,625 ft) reach of the LTC following storm events. Seepage flow rates ranged by two and a half orders of magnitude 4 to 931 L d^{-1} (1 to 246 gal day^{-1}), with an average of 174 L d^{-1} (46 gal day^{-1}) with sediment concentrations as high as 660 g L^{-1} (660,000 ppm) in situ. In contrast to the gully sediment load, seepage erosion sediment is predominantly coarse grained and will likely be retained within the stream channel. However, seepage erosion facilitates failure of overlying bank material that is predominantly fines. Integration of variably-saturated flow codes with streambank stability models by Chu-Agor et al. (forthcoming) and Fox et al. (2007b) have shown that undercutting of streambanks by seepage erosion is a key mechanism of bank failure at LTC. The relative proportion of sediment from eroded surface soils and entrained streambank failure material in the fine suspended sediment of LTC is being determined (Wilson et al. 2008) using ratios of naturally occurring radionuclides (^{7}Be and ^{210}Pb). These data will differentiate the eroded surface soil from the streambank sediment to quantify these sediment contributions to the total sediment yield.

Summary and Conclusions

There have been major changes in the Yalobusha River watershed and the surrounding region as a result of the conservation title of the 1985, 1992, 1997, and 2002 farm bills. This has included a major shift of cropland, particularly on highly erodible lands, to permanent cover of grass and/or trees due to enrolment in CRP. In addition, the remaining cropland is almost exclusively on less erodible land and is managed with cropping and tillage systems, such as no-till, buffer strips, contour terraces, etc., that enable production while attaining conservation compliance requirements. To date, general findings are that (1) sediment contributed by flashy hydraulic stream response, especially to storms, is the primary cause of stream impairment; (2) CRP, predominantly planting of pine trees, is the most prevalent CP by acreage within the TCW; and (3) the combination of incised channels and a dramatic shift in landuse to CPs such as CRP have resulted in streambank failure and gully erosion being the primary sources of current sediment yields within the watershed. This paper estimated that gully erosion accounts for 54% of the sediment from the TCW and combined with sediment from streambank failure may account for nearly the entire sediment yield.

It was also found that (4) the most common CP in TCW to control gully erosion is to install grade stabilization structures, commonly referred to as drop-pipe structures. On average, 58 small drop pipes have been installed annually through the EQIP program and 5.4 large drop pipes have been installed annually by the US Army Corps of Engineers in the TCW. Similar grade stabilization structures have been installed for decades, through different programs and agencies. Some of the current installations are to replace old or failed pipes. Therefore, the total number of active drop pipes within the watershed and their longevity are not known at this time. Finally, (5) EQIP applications include estimates of the sediment yield reduction. From 1998 until 2005, the sediment yield reduction was calculated through a procedure developed by the Mississippi NRCS specifically for EQIP (USDA NRCS 2006). Since 2005, this value has been obtained using RUSLE. According to these NRCS procedures, drop pipes should reduce the annual sediment yield from 11.5 to 0.1 Mg ha^{-1} y^{-1} (5.13 to 0.05 tn ac^{-1} yr^{-1}). However, measurements have not been made to determine the accuracy of these sediment reduction estimates.

Further research will be needed to quantify the sediment reduction, both at the field and watershed scales, by monitoring soil losses from ephemeral gullies with and without drop-pipe structures, surveying of undisturbed gullies, along with monitoring of upstream and downstream sediment loads. Additionally, the land use, CPs, and soil distribution data compiled through this project (Reid-Rhoades et al. 2008) will enable watershed modeling to determine how effective the CPs established since 1985 have been in reducing sediment yield.

Figure 7

Annual soil loss by gully erosion derived from Environmental Quality Incentives Program applications and the number of drop pipes installed through Environmental Quality Incentives Program.

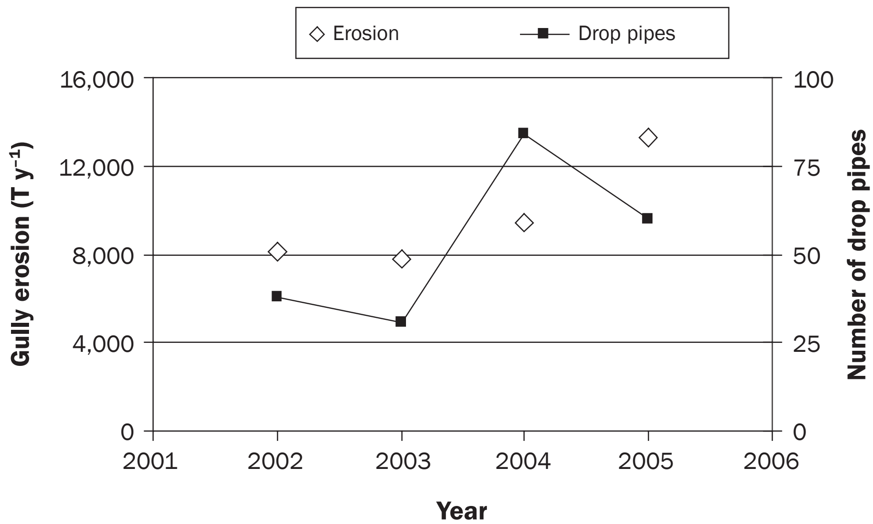


Figure 8

Survey results at selected times for the large gully in the Little Topashaw Creek subwatershed.

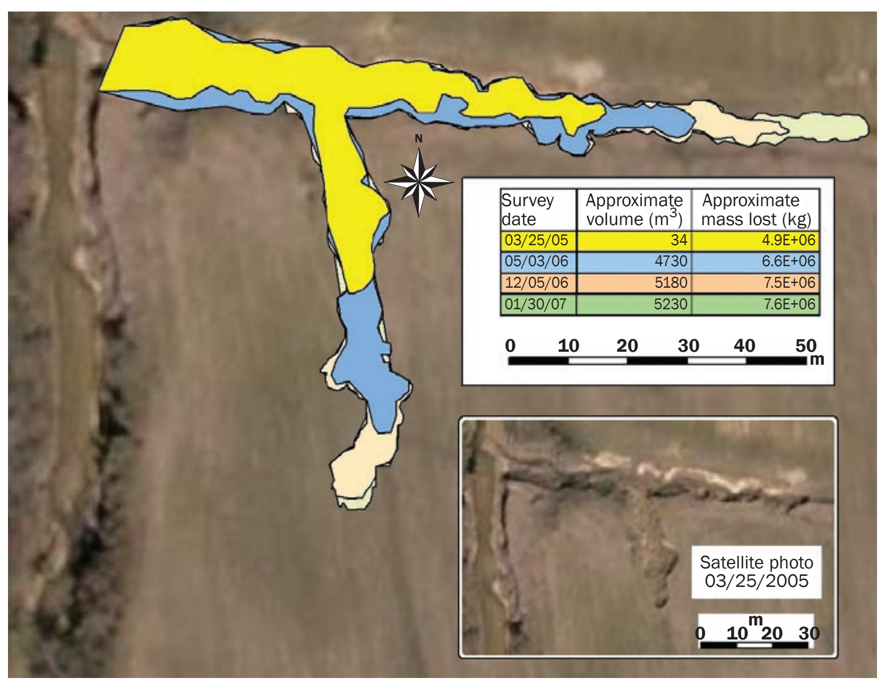


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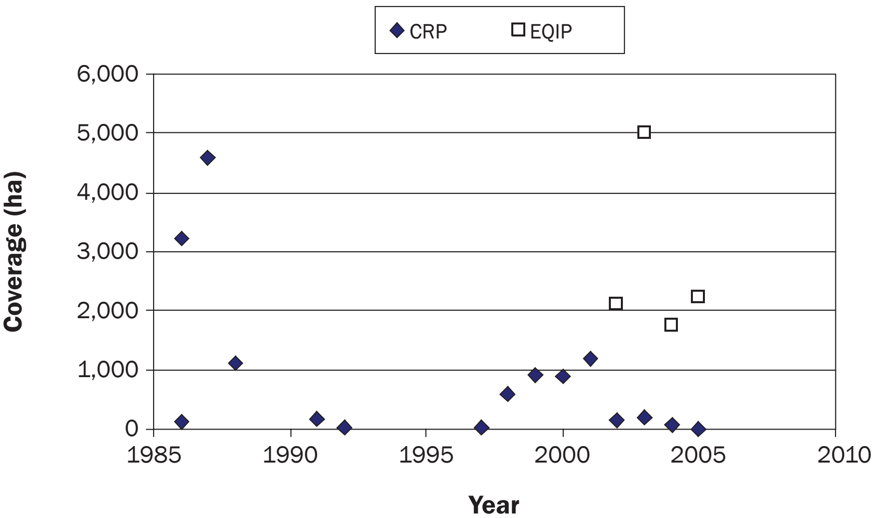
Figure 9
Total area treated under Conservation Reserve Program (CRP) and Environmental Quality Incentives Program (EQIP), not including grade structures, in the Topashaw Canal watershed during the period of interest.



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